DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350

IN REPLY REFER TO
Ser 455/390693
11 February 1982

Dear Mayor Feinstein,

This letter is a further response to the January 18, 1982 query from your Assistant Director of Environmental Health Services regarding reported radioactive contamination of San Francisco Bay in 1946. His query was prompted by certain media articles which indicated the Navy sold radioactively contaminated sand to contractors and dumped into the bay acid which had been used to clean Navy ships following Operation CROSSROADS in July 1946.

The Navy provided an initial response to this query in the form of a news release on January 22, 1982. A further review of records of the decontamination of ships at San Francisco shows that great care was exercised to limit radiation exposure in the San Francisco area, that radioactive material was disposed of properly, and that only after extensive testing was it determined that sand without marine growth and certain acid solutions used in cleaning would be safe for normal disposal. Other points of this review are as follows:

a. Most ships returning to San Francisco were initially decontaminated at Bikini or Kwajalein. San Francisco was chosen as a final decontamination point because of favorable anchorages, shipyard facilities, and the availability of radiological laboratories at the University of California.

b. Sand used for sandblasting the hulls and acid used in cleaning the salt water piping of CROSSROADS ships were disposed of at sea from the start of the decontamination project until December 4, 1946.

c. After December 4, 1946, and following radiological analysis and evaluation of decontamination procedures by the University of California and Navy scientists, Naval ships and shipyards were authorized to dispose of used acid solutions into harbor waters. Records of the quantities of radioactive fission products which were discharged into San Francisco Bay could not be located. As a result of the Navy's current review, it is estimated that a maximum of 1 curie of fission products for the most highly contaminated ship could have been disposed of in this manner. It is concluded that the total quantity of fission products which could have been disposed of in San Francisco Bay as a result of all nine ships decontaminated after December 4, 1946, could also be discharged today from a commercial nuclear facility and meet the requirements of the Nuclear Regulatory Commission.

d. Additionally, after December 4, 1946, sand without rust and marine scrapings did not require special disposal. The Navy has been unable to locate any records concerning actual disposal of this sand.

Beginning in 1957, the Navy has conducted environmental monitoring of the San Francisco Bay region and other selected locations. This environmental monitoring (water, sediment, plant and animal samples) of the San Francisco Bay area has not detected any difference over the low levels detected in other harbors. Those levels detected have been due to natural radioactivity and worldwide fallout from atmospheric weapons testing.

To further assist you, a more detailed description of the decontamination process is enclosed.

I conclude that the environmental standards established by the University of California and the Navy, as early as 1946, meet current regulations and that a present day review affirms that no danger to people living in the Bay Area resulted from the decontamination of ships present at the CROSSROADS tests.

I trust that this information answers your questions.

Sincerely,

A. M. SINCLAIR
Rear Admiral, U. S. Navy
Deputy Chief of Naval
Operations (Logistics)
(Acting)

The Honorable Diane Feinstein
Mayor, City of San Francisco
City Hall
400 Van Ness Avenue
San Francisco, California 94102

Enclosure

Decontamination of U.S. Navy Ships Involved in Operation CROSSROADS

Operation CROSSROADS was a two-detonation atmospheric test conducted in July 1946 at Bikini Atoll. Following the test, 52 support and target ships returned to San Francisco for decontamination at the San Francisco Naval Shipyard and the Mare Island Naval Shipyard.

Attachment one is a list of those ships which were decontaminated in the San Francisco area.

All ships at CROSSROADS had radioactive contamination to some degree. Contamination on support ships was limited to the hull below the water line and the internal salt water piping systems such as the evaporators, condensers and fire mains.

The low level of radioactive material suspended in Bikini Lagoon was concentrated principally in the marine growth, rust and salt scale which resulted from contact with sea water. Target ships were also contaminated above the water line as a result of the base surge after Test BAKER.

An extensive program to decontaminate these ships was initiated in August 1946 which lasted into mid-1947. Most ships proceeded o Kwajalein Atoll for initial decontamination. Beginning in mid-ugust, designated ships started to return to the United States for final decontamination. San Francisco was a decontamination point because of the availability of technical personnel, shipyard facilities, and radiological laboratories at the University of California.

The internal salt water piping systems were flushed with various concentrations of acid including muriatic acid (hydrochloric acid) to remove the radioactive marine growth and scale. After use, the residue contained very low concentrations of radioactivity. Calculations indicate that if an individual were inclined to drink two quarts of the bay water each and every day for a year the accumulated dose would be less than one five hundredth the dose that Bay Area residents receive from other natural sources.

Decontamination of the underwater portions of the hull consisted of removal of the rust and marine growth by scraping while in a dry dock. If additional decontamination was required, the hull was sandblasted.

During November 1946, the results of the University of California testing of ship materials, as well as results from the first ship decontamination efforts, became available. They indicated the level of radioactive material in the sand did not

present a hazard to personnel, and special disposal procedures were not required since most of the radioactivity was removed in the marine growth prior to sand blasting.

A three-volume report entitled "Director of Ship Material Technical Report, Radiological Decontamination of Target and Non-Target Vessels" (Operation CROSSROADS) contains the original report of the decontamination project and is the basis for the information in the media articles. A copy of these documents, commonly known as XRD-185, 186 and 187, is included as attachment two. Volume 3 (XRD-187), pages 102-115, contains a memorandum with the minutes of a meeting held November 27, 1946 at which the decisions was made to change the procedures for disposal of the sand and acid. On December 4, 1946 Naval Shipyards were advised by message (XRD-187, page 53) and on December 17, 1946 by letter (XRD-187, pages 54-56) of the changes to the disposal procedures.

The fact that no radiological hazard existed from the sand or dilute acid solutions was repeatedly emphasized by Navy and University of California scientists in the 1946 documents. Examples of their conclusions are contained in XRD-185, pages 56, 59, 60 and XRD-187, pages 107, 108, 109 and 113. The Navy has further analyzed the radiation measurements and the quantity of fission products and has determined that even in the unlikely event a person was constantly exposed to all the sand used for sandblasting, the lifetime (50 year) dose would only be 0.54 rem gamma. The current Federal guidelines for exposure to the general public is 0.5 rem per year.

No environmental monitoring records for San Francisco Bay have been found for decontamination operations conducted in 1946. This is not surprising since no requirements had been established at the time of Operation CROSSROADS. The Navy commenced a routine environmental monitoring program at selected locations in 1957, among which San Francisco Bay is included. Monitoring in San Francisco Bay is conducted at Hunters Point, Mare Island Naval Shipyard, and Alameda Naval Air Station. This monitoring has not detected any increase in general background radioactivity over the low levels detected in other harbors throughout the country from natural radioactivity and worldwide fallout from atmospheric weapons testing.

ATTACHMENTS:
1. Ships Decontaminated in San Francisco
2. XRD 185, 186, and 187

LIST OF CROSSROADS SHIPS
DECONTAMINATED AT SAN FRANCISCO

Before 4 December 1946

1. USS ACHOMAWI (ATF-148)
2. USS ARTEMIS (AKA-21)
3. USS ATA-187
4. USS ATA-192
5. USS AVERY ISLAND (AG-76)
6. USS BARTON (DD-722)
7. USS BENEVOLENCE (AH-13)
8. USS BLADEN (APA-63)
9. USS BOTTINEAU (APA-235)
10. USS BOWDITCH (AGS-4)
11. USS CHIKASKIA (AO-54)
12. USS CONYNGHAM (DD-371)
13. USS CORTLAND (APA-75)
14. USS DELIVER (ARS-23)
15. USS DENTUDA (SS-335)
16. USS DIXIE (AD-14)
17. USS ENOREE (AO-69)
18. USS FILLMORE (APA-83)
19. USS GENEVA (APA-86)
20. USS JAMES M. GILLIS (AGS-13)
21. USS JOHN BLISH (AGS-10)
22. USS LAFFEY (DD-724)
23. USS LOWRY (DD-770)
24. USS LST-861
25. USS LST-871
26. USS LST-989
27. USS MOALE (DD-693)
28. USS NIAGARA (APA-87)
29. USS O'BRIEN (DD-725)
30. USS PALMYRA (ARST-3)
31. USS PARCHE (SS-384)
32. USS ROCKBRIDGE (APA-228)
33. USS SAN MARCOS (LSD-25)
34. USS SEARAVEN (SS-196)
35. USS SKATE (SS-305)
36. USS SKIPJACK (SS-184)
37. USS TUNA (SS-203)
38. USS WALKE (DD-723)

After 4 December 1946

1. USS ATR-40
2. USS CEBU (ARG-6)
3. USS FULTON (AS-11)
4. USS HENRICO (APA-45)
5. USS LST-388
6. USS LST-881
7. USS ROCKINGHAM (APA-229)
8. USS ROCKWALL (APA-230)
9. USS WIDGEON (ASR-1)
*10. USS INDEPENDENCE (CVL-22)
*11. USS GASCONADE (APA-85)
*12. USS CRITTENDEN (APA-77)
*13. USS LCI-549
*14. USS LCI-615

* Did not require acid cleaning of piping systems.

12 FEB 1982

RELEASE OF SAN FRANCISCO DECONTAMINATION STUDY

A U. S. Navy study completed (this week) has concluded that radioactive decontamination of 52 Navy ships conducted in the San Francisco Bay Area in late 1946 posed no danger to the environment or populace of the area then or now. Details of the study were provided to Mayor Diane Feinstein of San Francisco (today) in a letter from the Deputy Chief of Naval Operations for Logistics.

The study consisted of an extensive review of all available records from the decontamination period and more recent information examined in light of present guidelines. The review confirmed preliminary findings released in January which indicated that the environmental standards established by the Navy in conjunction with the University of California as early as 1946, meet current regulations for limiting radiation exposure. The review further concluded that all radioactive material from the decontamination effort was disposed of properly at the time.

The 52 ships were brought to the Bay Area for final radiological decontamination after having participated in Operation Crossroads, a two-detonation atmospheric test conducted at Bikini Atoll in the Pacific in July 1946. San Francisco was chosen because of favorable anchorages, shipyard facilities, and the availability of radiological laboratories at the University of California. Most of the ships that returned to the Bay Area were initially decontaminated at Bikini or Kwajelein Atoll. Final decontamination was accomplished at San Fancisco and Mare Island Naval Shipyards.

Initially rust and marine growth scraped from the underwater hulls of the vessels in drydock and the acid used to flush internal water piping systems were disposed of at sea in sealed containers. If additional decontamination was required externally, the hulls were sandblasted. Used sand which then contained particles of marine growth was always disposed of at sea.

During November 1946, results of University of California tests indicated the level of radioactive material in the sand which did not contain marine growth and the acid solutions used to clean the piping presented no hazard to personnel and special disposal procedures were not required.

Therefore, the sand which was used in final sandblasting of hulls after December 4, 1946, and which did not contain rust or marine scrapings, was no longer disposed of in any special way. The Navy has been unable to locate any records concerning actual disposal of this sand.

However, further analysis of the radiation measurements and the quantity of fission products showed that even if a person were to be exposed for the past 35 years to all the sand used for sandblasting, he would receive less radiation exposure than current Federal limits for a member of the general populace in one year.

Also beginning on December 3, 1946, the shipyards were authorized to dispose of the acid, which did contain extremely low levels of radioactivity, into the harbor. The limits placed on radioactivity levels safe for dumping at the time still meet current Nuclear Regulatory Commission standards.

With respect to any ingestion hazard, calculations indicate that an individual would have to drink 250 gallons of this water every day for a year to receive an exposure equal to that which he would receive from natural radiation sources during the same time period.

Although no environmental monitoring records have been found for decontamination operations conducted in 1946, the Navy did commence a routine environmental monitoring program at selected locations in 1957. Monitoring points within the San Francisco Bay Area included Hunters Point, Mare Island and Alameda Naval Air Station. This monitoring has not detected any increase in general background radioactivity over the low levels detected in other harbors throughout the country from natural radioactivity and worldwide fallout from atmospheric weapons testing.

San Francisco Chronicle 5
Sat., February 20, 1982

CAPT LOEFLER
X 44582

Navy Findings on A-Waste in Bay

The U.S. Navy claimed yesterday that contamination left in San Francisco Bay in 1946 by 32 radioactive U.S. ships has not been dangerous to the welfare of either the environment or residents here.

It was revealed last month that the ships were brought to San Francisco for cleaning after participating in nuclear weapons tests at Bikini Atoll in the Pacific that tested the effectiveness of the weapons on military hardware.

Most of the ships, the Navy said, were decontaminated on the scene. It said the ships were brought to San Francisco afterward for final decontamination.

The Navy said its findings, based on a recent review of all available records from the period, show the Navy followed environmental standards established by the University of California as early as 1943. The standards conform to current laws limiting radiation exposure.

Debris scraped from the hulls, said used to flush water piping systems on board and some sand used in sandblasting the radioactive hulls were disposed of at sea in sealed containers, the Navy said.

Although some radioactive waste was flushed into San Francisco Bay, the Navy said its calculations indicated that a person would have to drink 286 gallons of that water a day for a year in order to receive an exposure equal to that received from natural radiation during the same period.

DASS - TO CDR TAYLORS OFFICE

- LCDR - JURKOWSKY

11 February 1982

OPERATION CROSSROADS SHIPS DECONTAMINATED AT
SAN FRANCISCO AFTER 1 DECEMBER 1946
(All Dates 1946 Unless Specified)

NAME OF SHIP	DATE DEP BIKINI OR KWAJ	DATE ARR CONUS PORT	DATE ENTER DRYDOCK	DATE LEFT DRYDOCK	OPER CLEAR	FINAL CLEAR	REMARKS
1. USS ATR-40	Aug 21	Dec 1	No	No	Dec 17	Dec 21	Drydocked Pearl, Nov 5-19 Decon at NSYSF, Dec 10-16
2. USS CEBU (ARG-6)	Aug 23	Oct 28	No	No	Dec 16	Dec 16	Via San Diego, San Pedro Decommissioned Jun 30, 1947
3. USS CRITTENDEN (APA-77)	Dec 1	Jan 1, '47	No	No	Target		No internal piping contam. Sunk Oct 5, 1948
4. USS FULTON (AS-11)	Aug 28	Sep 18	Nov 21	Dec 27	Dec 24	Jan 10, '47	Acid cleaning Dec 16
5. USS GASCONADE (APA-85)		Jan 27, '47	Apr 24, '47	May 20, '47	Target		No internal piping contam. Sunk Jul 21, 1948
6. USS HENRICO (APA-45)	Aug 16	Aug 29	Jan 17, '47	Jan 27, '47	Jan 28, '47	Feb 1, '47	Initial decontamination San Diego Nov
7. USS INDEPENDENCE (CVL-22)	Apr 15, '47	Jun 16, '47	No	No	Target		No internal piping contam. Sunk Jan 26, 1951
8. USS LCI-549		Jun, '48			Target	Estimate Aug '48	Sold to the Lerner Co., Fort Stanford, St. Alameda, California, 2 Aug 49
9. USS LCI-615		Jun '48			Target	Estimate Aug '48	Sold to the Lerner Co., Fort Stanford, St. Alameda, California, 2 Aug 49
10. USS LST-388	Oct 2	Oct 14	No	No	Dec 5	Dec 13	Decommissioned Feb 1, 1947 Probably decontamination completed prior Dec 1
11. USS LST-881	Aug 23	Oct 2	Nov 2	Nov 18	Dec 13	Dec 23	
12. USS ROCKINGHAM (APA-229)	Aug 23	Sep 12	Jan 6, '47	Jan 17, '47	Dec 4	Jan 18, '47	
13. USS ROCKWALL (APA-230)	Aug 24	Sep 12	Dec 13	Jan 6 '47	Dec 13	Jan 10, '47	Mar 15 '47 Decommissioning
14. USS WIDGEON (ASR-1)	Sep 11	Nov 12	No	No	Dec 17	Dec 21	Decontaminated- Nov-Dec Out of commission Feb 47

San Francisco, CA
(San Francisco Co.)
Examiner
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(Cir. Sat. 118,356)

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FEB 20 1982

Allen's P. C. B Est. 1888

Navy says all's well with its once-hot ships

3599

Decontamination of 52 radioactive U.S. Navy ships in the Bay Area in 1946 posed no danger to the environment or residents of the area then or now, the Navy says.

The study, which involved a review of all available records from the period and more recent information, confirmed preliminary findings released last month, the Navy said. Those findings indicated that environmental standards established with the University of California as early as 1946 meet current regulations for limiting exposure to radiation.

An earlier Navy denial followed published reports, based on documents obtained under the Freedom of Information Act by The Examiner and other news organizations, that radioactive materials had been dumped into the Bay.

The ships were brought to San Francisco for final decontamination after taking part in Operation Crossroads, a pair of atmospheric atomic tests at Bikini Atoll in the Pacific. Most of the ships were decontaminated initially on the scene, the Navy said.

Debris scraped from the hulls, acid used to flush water piping systems onboard and some sand used in sandblasting the ships was disposed of at sea in sealed containers, the Navy report said.

Some slightly radioactive debris was released into the harbor, the Navy said, but added that calculations indicate a person would have to drink 250 gallons of that water a day for a year to receive an exposure equal to that which he would receive from natural radiation during the same period.

210-UP
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Room 2E341, Pentagon

MEDIA QUERY

DATE 18 JAN TIME 1800 ACTION OFFICER(S) LT SCHMERMUND

QUERY FROM Paul Schwabacher-Asst.Dir. Bureau of Environmental Health Services-San Francisco PHONE 415-558-4846

REPORTER'S DEADLINE 1500 19 JAN 82

SUBJ: The reported radioactive contamination of San Francisco Bay

Background Statement: Mr. Schwabacher is calling for the Director of Environmental Health Services, Dr. Silverman, and the Mayor of San Francisco, Mayor Feinstein. Specifically, he is seeking guidance in response to a number of media stories about the Navy sandblasting and acid cleaning Navy ships which had been exposed to radioactivity from nuclear blasts.

Q1. Was the radiation from the Navy vessels high-level or low-level radiation?

Q2. What type of radiation was it,e.g.,Strontium,Iron, or Cobalt,etc?

Q3. What happened to the sand leftover from the sandblasting?

Q4. If the sand was given to local contractors, which contractors received it and what did they do with it?

Q5. Has San Francisco Bay been monitored for radioactivity since 1946?

Q6. Is the Bay presently being monitored for radioactivity, and if not, are there now plans to do so?

CNX Query--- Matter turned over to Defense Nuclear Agency, LCOL Keller PH 325-7095(Telecopy #325-7366)

SOURCE

COORDINATION:
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ACTION OFFICER'S CHOP

OI-210/OI-211 OI-21 OI-02

RELEASE AUTHORIZED CNX

TIME/DATE ANSWERED

ANSWERED BY

OI-210/OI-211 REVIEW 19

COPY TO/FILE

[redacted]RY NUMBER 0066

January 22, 1982

PROPOSED STATEMENT (INTERIM) FOR RELEASE IN SAN FRANCISCO

The information in the report cited in the San Francisco Chronicle of January 15, 1982, page 4, discussing the "San Francisco Bay and Old A-Tests" was contained in a three-volume report entitled "Director of Ship Material Technical Report, Radiological Decontamination of Target and Non-Target Vessels" Operation CROSSROADS. These volumes, commonly known as XRD 185, 186, and 187, were declassified by the Navy in 1949 and released publicly as early as 1979. This report includes a statement by Dr. Hamilton (then associated with the University of California) that "the quantities (of fission products) involved entail absolutely no health or security hazard".

The Navy is currently searching for and reviewing documents and other historical data which deals with decontamination efforts of ships in San Francisco in 1946 to insure that Dr. Hamilton was correct in his assessment. The ships were involved in atmospheric nuclear tests termed Operation CROSSROADS at Bikini Atoll.

Preliminary investigation indicates that decontamination of the ships was accomplished using safe, technically advanced methods. Initially acid and sand used in the decontamination process, and which contained very low levels of radioactivity, was dumped at sea. After December 17, 1946, dumping of the diluted acid in the Bay was authorized. This acid was a mixture of dilute hydrochloric acid and citric acid (the same acid present in orange, lemon and grapefruit juices). Hydrochloric acid (sold commerically as muriatic acid and currently used for swimming pool treatment) disappears immediately in sea water and is undetectable within five minutes. The Navy has no reason to believe any hazard to the environment or populace of San Francisco existed then or currently exists.

The Navy has assigned personnel to a research effort which involves examination of documents over 35 years old. A review of that material is now being accomplished to determine specifically what ships were decontaminated in the San Francisco Bay area, the quantity of acid and sand involved, levels of radioactive contamination and disposition of material if possible.

Additional information will be released to the public as soon as possible when a more detailed study is accomplished.

Tribune/TODAY Thursday, January 23, 1986

Telecopy to:
CAPT Loeffler

Navy says Bay A-test dump no S.F. hazard

From Tribune and wire reports

SAN FRANCISCO — The Navy said Friday the acid and sand it used to decontaminate ships in the 1946 atomic tests and dumped in San Francisco Bay wasn't and isn't a hazard to the urban Bay Area.

The claims came it has been heightened by reports this month that the Navy may now dump decommissioned reactors from obsolete nuclear submarines onto the Pacific Ocean's floor off Cape Mendocino in the coming 20 years.

The news was followed by a resolution by the state Senate Rules Committee urging President Reagan and the Congress not to dump nuclear wastes in the oceans.

The denial of hazard from the dumped acid and sand from the 1946 tests was made Friday in a Navy statement commenting on news stories published last week that were based on documents obtained under the Freedom of Information Act, saying the materials were dumped here.

It also was recalled that a dozen ships employed in the Bikini Atoll were later anchored in California ports, and some eventually were scrapped in the Pacific.

Cleaning fluids were dumped in the ocean at first, and later in the Bay, and sand used for cleaning was sold for use as fill with nothing said about its origin.

The Navy studied the old documents a week before issuing its statement Friday and said its study is continuing and it intends to release more information when a detailed review of the documents is completed.

Its statement said the information was in a three-volume report declassified in 1946.

That report included a judgment by a University of California adviser identified only as Dr. Hamilton that the amount of fission products involved "entail absolutely no health or security hazards."

According to Friday's statement the acids were dilute and became undetectable in sea water within five minutes, and the acids and the sand contained very low levels of radioactivity.

"The Navy has no reason to believe any hazard to the environ of populace of San Francisco existed then or currently exists," Friday's statement said.

MEMORANDUM

21 January 1982

MEMO FOR: NNTPR

FROM: J. Goetz, R. Weitz

SUBJECT: Disposal of Contaminants from Non-Target Ships

SITUATION:

Approximately 125 tons of blast sand, used to clean the USS Rockbridge at San Francisco Naval Shipyard in early October 1946, was sold to a contractor for construction (fill) purposes on or about 1 January 1947.

PROBLEM:

What was the residual radiation hazard of the blast sand in an extreme exposure situation?

DISCUSSION:

The Rockbridge was one of the more contaminated ships from Operation Crossroads to have been decontaminated at San Francisco. Decontamination consisted of scraping the marine growth (subsequent disposal at sea) and sandblasting the rust and scale to reduce the intensity to background level. The blast sand had a residual intensity (beta plus gamma) of .002 - .005 R/day, the readings having been taken on the floor of the drydock (p. 42, XRD-185), on or about 4 October 1946.

The intensity of the blast sand, for purpose of high siding the estimate, is assumed to be .005 R/day gamma. It is also assumed that the radioactivity in the sand decays according to $t^{-1.2}$ (normal fission product decay). If the sand were used as an earth cover, with personnel constantly standing thereon, the lifetime (50-year) dose is as follows for several exposure start dates:

Exposure start date	50-year dose (rem)
1 Oct 46	.72
1 Nov	.63
1 Dec	.58
1 Jan 47	.54
1 Feb	.51

Using the same decay and exposure schemes, the incremental dose to personnel from 1 January 1947 to various times are as follows:

Exposure Termination	Dose (rem)
1 Feb 47	.031
1 Mar 47	.057
1 Jan 48	.14
1 Jan 57	.41
1 Jan 97	.54

50 YR DOSE

It should be noted that the above values are assumed to be gamma only. In actuality, the intensity of contaminants of this age is predominantly beta, and therefore not a whole body external hazard. Beta-gamma intensity ratios of 5-10 to 1 are not uncommon, and would serve to reduce the above whole body doses by the same amount.

DISPOSAL OF HULL CONTAMINANTS, CROSSROADS NON-TARGET SHIPS

The plutonium hull contamination of a typical ship decontaminated in San Fransicso was on the order of 100 μg. This is inferred from XRD-187, pp. 56, 109, 110. The fission product hull contamination was about 1 Curie.

The primary hazard of plutonium, an alpha-emitter, comes from entry into the body by inhalation. Therefore, the particles must be of respirable size, estimated to be on the order of one micron. Only about 10 percent of all inhaled plutonium is eventually absorbed into the bloodstream, the other 90 percent being exhaled or otherwise expelled from the body. Most of the plutonium that enters the bloodstream is deposited in the bone (66 percent) and in the liver (23 percent). Within a few months, 80 to 90 percent of the total body burden is found in the skelton. The biological half-life is about 200 years.

It is assumed that all 100 μg of plutonium remained on the hull after scraping, but was completely removed by sandblasting. Hence, all 100 μg became intimately mixed with 125 tons (as much as 400 tons for some ships) of blast sand, subsequently used as fill material.

The fission product contamination at about 120 days consisted of the following radioisotopes that, if inhaled, contributed to 50-year whole body dose or to a 50-year bone dose (the two worst cases).

*Niobium - 95	(19%)
*Zirconium - 95	(14%)
*Ruthenium - 103	(10%)
*Ruthenium/Rhodium - 106	(5%)
*Cerium - 141	(8%)
Yttrium - 91	(7%)
Strontium - 89	(6%)
Cerium/Praseodemium - 144	(6%)

*Also contributes to external gamma dose

Promethium - 147	(2%)
Strontium - 90	(.14%)

(Numbers in parenthesis indicate the relative disintegration rate of the isotopes.)

Two scenarios are postulated. One, that the sand was dumped from trucks in a fill site over an equivalent period of about eight dumping hours, causing heavy dust conditions. Two, that the sand was spread over a playground to a depth of about one-inch (covering an area of 30,000 square feet, or approximately 175 feet square).

PLUTONIUM INHALATION

The Pu concentration in the sand is:

$$100\ \mu g/125\ T = 100\ \mu g/210\ m^3 = .48\ \mu g/m^3$$

For the first case, it is assumed that the sand, when dumped from trucks, results in a heavy dust cloud with a density of one-thousanth that of the compacted sand. The Pu concentration is thus diluted accordingly, and is therefore:

$$4.8 \times 10^{-4}\ \mu g/m^3$$

Using an inhalation rate of 1.3 m^3/hr over a dumping period of 8 hours, the total Pu inhaled is:

$$(4.8)(10^{-4})(1.3)(8) = 5 \times 10^{-3}\ \mu g$$

The specific activity of plutonium is .064 Ci/g. Total activity inhaled is:

$(5)(10^{-3})(.064) = (3.2)(10^{-4})\ \mu Ci$

The 50-year inhalation dose factor (bone) is 912 rem/μCi inhaled. The dose is therefore:

$(3.2)(10^{-4})(912) =$ .29 rem (6 mrem per year)

For the second case, the playground sand is assumed to be completely resuspendable to the full depth of one inch, with a resuspension factor of $10^{-4}\ m^{-1}$. A child plays on this playground for eight hours per day, for five years. The Pu concentration in the sand is:

$.48\ \mu g/m^3 = .012\ \mu g/m^2$

The plutonium inhaled (assuming a breathing rate of 1 m^3/hr) is:

$(.012)(\ g/m^2)(10^{-4})(1/m)(8)(365)(5)(hrs)(1)(m^3/hr) = 0.18\ \mu g$

The 50-year dose (bone) is therefore:

$(.018)(.065)(912) =$ 1 rem (20 mrem per year)

FISSION PRODUCT INHALATION

For the first case (8 hours of heavy dumping dust), the estimated dose from fission product inhalation uses the same ratio as for plutonium inhalation to the total plutonium present, to determine the fission products inhaled, which is:

$3.2 \times 10^{-4}\ \mu Ci$ inhaled/6.4 μCi (100 mg) present = 50×10^{-6}

The dose factors for 1 micron inhaled particles are found in TM-190. They are as follows:

	50-year Dose Factor (rem/ Ci)	
Isotope	Whole Body	Bone
Nb-95	1.94 (-3)	1.22 (-3)
Zr-95	5.55 (-3)	9.15 (-3)
Ru-103	1.98 (-3)	9.12 (-4)
Ru/Rh-106	.0618	8.76 (-3)
Ce-141	1.15 (-3)	3.35 (-4)
Y-91	5.67 (-3)	.0225
Sr-89	3.89 (-3)	.0338
Ce/Pr-144	.0468	.0218
Pm-147	5.30 (-3)	6.58 (-3)
Sr-90	.24	3.00

The 50-year dose commitment for each of the isotopes is determined from the amount inhaled, the contribution fraction (relative disintegration rate), and the dose factor. For Niobium,

$$\text{Whole Body Dose} = (1\ \text{Curie})(50\times10^{-6})(.19)(1.94\times10^{-3}\ \text{rem}/\mu\text{Ci})(10^{6}\ \mu\text{Ci/Ci})$$
$$= 0.18\ \text{rem}$$

In like manner, doses from each isotope are calculated. The results are as follows:

	50-year Dose Factor (mrem)	
Isotope	Whole Body	Bone
Nb-95	18	12
Zr-95	39	64
Ru-103	10	5
Ru/Rh-106	155	22
Ce-141	5	1
Y-91	20	79
Sr-89	12	101
Ce/Pr-144	140	65

Pm-147	5	7
Sr-90	17	210
Total Dose	420 mrem	570 mrem

For the playground case, the 50-year doses are roughly three times the above (based on the Pu cases).

MEMORANDUM

1 February 1982

TO: NWTPR

FROM: J. Goetz

SUBJECT: Acid Residue And Radioactivity From Decontamination of Crossroads Non-Target Ships

Approximately 6000 gallons of acid were used to clean the internal piping of the Rockbridge. The piping was contaminated with fission products and unburned plutonium, intimately mixed with the usual build-up in pipes, such as calcium carbonate. A typical cleansing reaction is:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

It is assumed that the pipe contamination on 1 December 1946 amounted to 1 Curie of fission products (about the same as hull readings, converted to activity) and 6.4 microCuries (100 μg) of plutonium, and that 90 percent of the radioactive materials were removed in the cleaning process, remaining intimately mixed with the salt and water residues. These residues were then placed in drums (55-gallon) for transport to disposal areas.

If the contents of these drums were diluted 4 to 1 as they were being dumped into a large body of water, the total dilution, together with the inherent shielding of water, would have rendered the material virtually harmless. For example, mixing the contents with a column of water 40 feet deep and 3000 feet in diameter (2.2 billion gallons) results in a dilution factor of 350,000. This results in a dilution of the original Curie of radioactivity to .13 $\mu Ci/m^3$. Considering that only the top 4 inches (10 cm) of activity can contribute to an above-water dose, the concentration at the surface is therefore .013 $\mu Ci/m^2$.

At 90 days after burst (1 December), the above concentration results in an intensity above the surface of:

$$\frac{.013}{256} = .00005 = 5 \times 10^{-5} \text{ mr/hr} .$$

(256 is conversion of $\mu Ci/m^2$ to mr/hr at 2160 hours)

The dose to a person exposed above this pool for 1 year (assuming no further dilution) is:

$$D = (5)(5 \times 10^{-5})(2160^{1-2})(2160^{-.2} - 10920^{-.2})$$

$$= 0.15 \text{ mr}$$

$$= 0.1 \text{ mrem in the year (December 1946 to December 1947)}$$

The plutonium in the residues presented no external hazard. When the drums were emptied, the plutonium likely mixed with the water as soluble plutonium oxide and was diluted to insignificance. The 100 μg, if diluted in 2.2 billion gallons of water (the 40-foot column), would present no significant contamination hazard.

WORKER HAZARD

An external gamma radiation dose hazard would have existed from the stored fission products. The concentration of these products was:

$$(.9 \times 1)/(6000) \times 55 = 8 \text{ mCi per drum}$$

As a point source of radiation, this concentration (assuming 0.7 Mev average energy) leads to 2.8 mr/hr (p. 32, Rad-Health Handbook). As a drum source, the self-shielding is a factor of three. Thus, the fission products would have presented an external gamma hazard to workers handling the drums. The 0.9 mr/hr intensity per drum leads to a maximum intensity of approximately 10 mr/hr for persons standing near an array of these drums.

INGESTION OF CONTAMINANTS
IN SAN FRANCISCO BAY

Assumptions:

1. 1 Curie of Crossroads Baker fission products and a 6.4 microCurie of plutonium are deposited in San Francisco Bay on 1 December 1946.

2. The contaminants are diluted in a segment of the bay that approximates a column of water 40 feet deep and 3000 feet in diameter.

3. The water is ingested by a representative person who drinks 2 liters per day for one year (presumably desalinated and heavily chlorinated).

The dose commitment is determined by apportioning the specific radioisotopic contribution to dose according to each isotope's relative disintegration rate at D+120 days, then using the appropriate ingestion dose factor to convert the activity ingested to a dose commitment. Dose commitments are then summed to determine the total (50-year) dose.

The total activity ingested (assuming no decay during the year) is:

$(.13\ \mu Ci/m^3)\ (2)(10^{-3})(365) = .095\ \mu Ci$

For Niobium-95, 50-year dose commitment (whole body) is as follows:

(Total Activity Ingested)(Activity Fraction)(Dose Factor) =
$(.095)(.19)(5.04 \times 10^{-4}) = .009$ mrem

In like manner, dose contributions from each isotope are calculated. The results are as follows:

Nb-95	(5.04)(-4)	.009 mrem
Zr-95	(5.45)(-4)	.007
Ru-103	(5.29)(-4)	.005
Ru/Rh-106	(5.94)(-3)	.028
Ce-141	(1.72)(-4)	.001
Y-91	(4.37)(-4)	.003
Sr-89	(1.80)(-3)	.010
Ce/Pr-144	(1.00(-3)	.006
Pm-147	(5.02)(-5)	.000
Sr-90	(9.45)(-2)	.013
Total 50-year whole-body dose commitment		.082 mrem

(whole-body dose factors in parentheses)

The plutonium ingestion would have resulted in a negligible dose. Specifically, the plutonium concentration in the 40-foot column is:

$$\frac{(6.4)(10^{-6})}{(7.88)(10^{12})} = 8.12 \times 10^{-19} \text{ Ci/liter}$$

For the two liters per day ingestion, the total annual ingestion is:

$$(8.12)(10^{19})(2)(365) = 5.9 \times 10^{-16} \text{ Ci}$$
$$= 5.9 \times 10^{-10} \mu\text{Ci}$$

The ingestion dose factor (50-year bone dose commitment) is 0.57 rem/μCi. Thus, the 50-year dose commitment is:

$$(5.9)(10^{-10})(.57) \times 3.38 \times 10^{-10} \text{ rem}$$

OPERATION CROSSROADS FACT SHEET

BACKGROUND

Operation CROSSROADS, the first peacetime oceanic atmospheric nuclear test series, occurred in July 1946 at Bikini Atoll in the Marshall Islands. The operation consisted of two detonations, Test ABLE on July 1 and Test BAKER on July 25. Both devices had a yield of 23 kilotons.

Approximately 37,000 naval personnel and 3,100 other military and civilian personnel participated in the operation. In addition, the test series was observed by members of Congress, members of the press, various government agency representatives, foreign dignitaries, and scientists.

CROSSROADS was conducted by Joint Task Force ONE which had been formally created in January 1946 by the Joint Chiefs of Staff. Bikini was chosen as the test site because it satisfied several criteria, i.e., (1) the lagoon provided a protected anchorage at least six miles in diameter, (2) it was a relatively unpopulated region situated at least 300 miles from an urban area and (3) the lagoon waters had fast currents which would carry the radioactivity away from fishing areas, steamship sea lanes and inhabited shores. Bikini Atoll natives, as well as natives from nearby islands were evacuated before the detonations.

The primary purpose of CROSSROADS was to determine the effects of an atomic bomb on naval vessels. Towards this end 84 of the 240 naval vessels placed under the command of Joint Task Force ONE were designated as target ships. These vessels represented nearly all types of ships and were anchored at various distances from ground zero at the time of the detonations. No attempt was made to arrange the vessels so that the tests would simulate use of the bombs against an actual fleet at anchor or at sea; rather, emphasis was placed on obtaining scientific and technical data which would serve as the basis for predicting what would happen in any of a great variety of tactical situations in the future.

Besides target vessels, a variety of Army and Navy equipment was exposed. In addition, an assortment of animals was housed aboard some of the target vessels to determine what symptoms resulted, how diagnosis might best be made and what treatments were effective. All test materials and animals were inspected carefully before and after each detonation.

Prior to each of the detonations, a rehearsal exercise was held to familiarize personnel with evacuation and reentry procedures. On the day preceding each detonation, target vessel crews began transferring to transport ships. Evacuation was often completed in the early morning of the test day at which time all non-target ships departed the lagoon. At the time of detonation no personnel were aboard any of the target ships or islands of Bikini Atoll.

Test ABLE

The first CROSSROADS event, Test ABLE, was detonated at 9:00 a.m. on July 1. The bomb was delivered by a specially prepared B-29 aircraft. The closest operating ship was 11.7 miles from ground zero. Minutes after the detonation, drone aircraft flew through the cloud to collect cloud samples while drone boats entered the lagoon shortly after to take water samples.

Test ABLE is known to have caused only minor radiological contamination to the lagoon and virtually no contamination to the non-target ships because the fire ball did not contact the surface of the water. The radioactive intensity of the water four hours after the detonation in a 0.8 square mile area roughly centered at the zeropoint was only 0.5 roentgens per 24 hours. Twenty-six hours later the intensity had decreased to 0.1 roentgen per 24 hours which was established as the maximum permissible exposure guideline. (A roentgen is a unit of radiation exposure which measures the effects of radiation on air but is widely used as a unit of biologic dose for gamma radiation.)

At 9:47 a.m. on July 1, radiological clearance was given to USS BARTON (DD-722) to approach the lagoon entrance and for six PGMs (radiological patrol boats) to follow. By 10:50 a.m. the PGMs had entered the lagoon.

Initial Boarding Teams (composed of the radiological safety monitor, medical safety officer, technical representatives of the Director of Ship Material and a photographer) and Salvage Unit personnel began survey operations four hours after Test ABLE. There was considerable radioactivity aboard target ships near the center of the array and there were a number of fires. However, by 2:30 p.m. the lagoon was declared safe for the return of all vessels. By evening all ships were safely anchored in temporary berths in the lagoon, well outside the area of contamination. By 8:30 p.m. initial boarding teams had boarded and radiologically cleared (found safe) 18 target ships. On July 2, inspection of target vessels continued. Five of the target ships sunk as a result of the blast. The maximum radioactivity on any ship surviving Test ABLE was a reading of eight roentgens per 24 hours measured on July 2 in a pool of water aboard USS ARKANSAS (BB-33). By the evening of July 2, 47 target ships were declared safe and were reboarded by all or part of their crews. That same day the islands of Bikini and Enyu were inspected and declared radiologically safe.

During the next few days target ship crews continued to return to their ships as rapidly as conditions permitted. By July 5 target ships had been rehabilitated to the extent necessary to permit preparations for the second CROSSROADS test.

Test BAKER

Test BAKER, the second CROSSROADS event, was detonated 90 feet beneath the surface of the lagoon at 8:35 a.m. on July 25. The closest non-target vessel was eight miles from surface zero.

The base surge resulting from this underwater test formed approximately 10 seconds after the blast and swept outward at 45 miles per hour engulfing the majority of the target vessels in its radioactive mist. Near the zeropoint the activity in the water was about 400 roentgens per 24 hours at one hour after the test. This reading decreased to the safe level of 0.1 roentgen per 24 hours five days later.

Drone aircraft flew through the cloud immediately after the detonation while drone boats penetrated the target array area within two hours after the test.

Radiological patrol boats followed the drone boats into Bikini Lagoon. By 11:00 a.m. USS FALL RIVER (CA-131) was stationed as harbor entrance control vessel and USS KENNETH WHITING (AV-14) was anchored inside the lagoon to permit technical personnel to recover instruments and cameras from the islands. At the same time the Director of Ship Material, located aboard USS RECLAIMER (ARS-42), and Initial Boarding Teams, housed aboard five ships of the Salvage Unit, entered the lagoon. In the following two hours, boarding teams examined and cleared a number of ships on the outer edge of the target array within the small area declared radiologically safe. These ships had escaped the heavy base surge of contaminated water resulting from the detonation. Meanwhile, eight technical ships of the Instrumentation Unit were approaching the lagoon and shortly after 2:00 p.m. anchored a few hundred yards inside the entrance. The majority of the operating ships remained outside the lagoon in their evacuation operating areas.

For several days drone boat radiological reconnaissance of the water in the lagoon continued to show a high degree of contamination, creating considerable difficulty in reboarding and salvage attempts. A "Red Line" and a "Blue Line" were established to indicate areas of severe (1 roentgen per day) and moderate (above 0.1 roentgen per day) contamination and plotted on charts. New charts were made every few hours at first and then at less frequent intervals. As the lines moved the radiological safety teams, damage control teams, salvage teams and key observers took advantage of every opportunity to safely inspect and service the target vessels. On July 27, contamination in the

area north of the target array subsided to a degree permitting ships of the Instrumentation Unit to move to their permanent berths, but the next day they were forced back down to the lower anchorage by movement of radioactivity in the vicinity of the target array.

Improvements in the radiological condition of the water permitted the discontinuance of drone boat reconnaissance activities on July 30. On July 30 and 31 all vessels, including those which had remained outside the lagoon since the day of the test, returned to their permanent berths in safe water. Vessels in the northern part of the anchorage accumulated radioactivity in their evaporators and on August 2 were shifted to uncontaminated berths near the lagoon entrance where they remained until August 7.

Meanwhile, intense radioactivity persisting in the target ships prevented inspection on a major scale and discouraged prospects of early reboarding. In an effort to reduce this radioactivity, decontamination procedures were established. Decontamination proceeded in two phases: a preliminary treatment consisted of washing down entire ships to remove the less firmly attached fission products and increase the tolerance period for boarding; a second operation consisted of scrubbing and scraping topside surfaces and removing the porous materials with high affinity for radioactive matter.

The Director of Ship Material staff members, working with the Salvage Units from the salvage ships, conducted the preliminary treatment. Special ships' crew teams carried out the subsequent process during short periods on board. Single washings with various solutions followed by high pressure sea water hosing proved partially successful, but several washings were necessary to improve conditions sufficiently to insure safe reboarding.

Post-BAKER

Decontamination efforts continued throughout August 1946. However, earlier in the month it became apparent that the tendency of radioactive material to concentrate and accumulate in the evaporators and marine growth and rust on hulls of ships operating in Bikini Lagoon made it mandatory to shift the base of operations to Kwajalein Atoll some 155 miles southeast of Bikini.

At the same time radiological surveys of target vessels indicated that many of them could not be boarded for sufficiently long periods to either prepare the ship for movement to Pearl Harbor or to fully assess the damage sustained. It was recommended that the more heavily contaminated ships be decommissioned at Kwajalein. This movement to Kwajalein began late in August and was completed early in September.

During the Post-BAKER operations in Bikini Lagoon all ships were carefully monitored and were never allowed to operate in highly radioactive water. However, evaporators and the marine growth on the ships' hulls at the waterline were found to build up concentrations of radioactive material that exceeded tolerance limits (0.1 R per 24 hours). Prior to departure all ships were given a special monitoring and a conditional radiological clearance. However, it was recognized that these ships could not be released for unrestricted operation, repair or disposition until they were decontaminated and proved to be definitely clear of radioactivity. Consequently, exposed CROSSROADS operating ships returned to West Coast naval shipyards for decontamination, monitoring and final clearance as required. Upon their return, several small boats and other porous material aboard some of these vessels were found to be radiologically hazardous and were sunk at sea. Underwater hulls were scraped and sandblasted if required and acid solutions were run through the salt water piping systems. By late-December 1946 approximately 50 percent of all CROSSROADS ships which returned to the West Coast had received final radiological clearance.

Bikini Atoll was completely evacuated on September 26, 1946. During October plans were made for the return of twenty target ships of particular interest from Kwajalein to Bremerton and Hunters Point Naval Shipyards and two to Pearl Harbor for detailed structural and radiological examination and experimentation. In addition, several operating ships were also sent to these shipyards for experimental work.

In October the preliminary examination and securing of target ships at Kwajalein was completed. On October 23, these vessels and their caretaking unit were turned over to the Atoll

Commander Kwajalein under the Commander-in-Chief, Pacific Fleet. The caretaking unit at that time consisted of the salvage tugs USS CONSERVER (ARS-39) and USS CURRENT (ARS-22), three LCIs, APL-27, YF-753, a shore based radiological safety unit, several small landing craft and an ammunition disposal unit. The ammunition disposal unit was charged with removing the ammunition from target ships scheduled for return to the west coast.

On November 1, 1946, Joint Task Force ONE was formally dissolved.

Of the 84 target ships used at CROSSROADS, 21 were sunk or destroyed at Bikini, 39 were sunk at Kwajalein, the PRINZ EUGEN sunk in the Kwajalein Lagoon, and one was sunk at an undetermined location in the Marshall Islands. Twenty-two returned to the United States.

RADIOLOGICAL SAFETY

The safety of all participants was paramount and special concern was given to those individuals who were scheduled to reboard target ships after the actual nuclear detonations.

The Radiological Safety Section (RAD SAFE) had the responsibility for monitoring personnel and minimizing their exposure to radiation. This section consisted of 303 civilians and military officers for Test ABLE and 258 for Test BAKER. During Test ABLE, 97 of the civilians had advanced degrees in medicine, physics, chemistry, biology, engineering and anatomy. Thirty-three officers were given a thorough two and a half month course conducted at Oak Ridge, Tennessee, University of Chicago, University of Rochester, Los Alamos, New Mexico, and the University of California. Training for the remainder of these highly qualified personnel was conducted on board the hospital ship USS HAVEN (AH-12) during its transit from the United States to Bikini Atoll. These specially trained personnel became the radiological monitors who were given the responsibility of insuring the safety of all personnel. All small craft and boarding parties had a radiological monitor on board. All monitors and a representative sample of crew members were issued film badges. The limitation in issuing film badges was based on the available supply of such badges.

All non-target ships departed the lagoon prior to both tests. The Radiological Safety Section was established on USS MOUNT MCKINLEY (AGC-7) prior to Test ABLE, and all reentry procedures into the lagoon were monitored and controlled by this center. It was the center's responsibility to direct all RAD SAFE units so that the safety of the task force could be best maintained.

For each test shot the RAD SAFE monitors were embarked on the photographic and reconnaissance aircraft to determine the atmospheric contamination and projected fallout patterns. This information was utilized in the movement of the support ships to minimize personnel radiation exposure. Later the RAD SAFE monitors accompanied all boarding parties to the target vessels. They were authorized to recall the party if the radiation levels encountered exceeded established guidelines. Boarding party personnel were required to wear specially issued work clothing which was later laundered separately under controlled conditions. Despite considerations of physical comfort, RAD SAFE plans called for sleeves to be rolled down, and gloves and proper footwear to be worn by personnel working on the target ships. Boats used for carrying working personnel back and forth to target vessels were monitored and scrubbed when necessary. All working parties passed through decontamination centers to detect any contamination and decontaminate if necessary. All

participants were warned that standing pools of water about the deck of target vessels could present potential risk and should be avoided. No dry dusting or sweeping was permitted and personnel were instructed never to eat, drink or smoke in any area suspected of being contaminated. No men with open cuts that were not securely covered and protected were permitted to perform work on target vessels. Officers in charge of working parties were instructed to be vigilant to detect and eliminate men from these groups who had any such wounds. To minimize contamination of the support vessels after Test BAKER, the ships were instructed to scrape off marine growth near the waterline and not to dismantle evaporators without a monitor being present.

A Medical Legal Board was formed during the early phases of the operation. This unit, drawn from outstanding radiologists throughout the country, acted in an advisory capacity with the Chief of the Radiological Safety Section in establishing policies for the Bikini Tests. Among the numerous problems raised were: use of drinking water in tanks on the target ships; use of water made by target and non-target ships during the blast; sleeping on decks topside; daily check of swimming beaches and water; exposure of personnel and contamination of non-target ships.

PERSONNEL EXPOSURES

It was common practice during CROSSROADS to obtain representative personnel exposure data for most ships by badging a percentage of the crew. Because of the limited number of film badges it appears that they were generally issued to those personnel or groups who had the greatest potential for exposure. The daily dose tolerance allowed for most personnel was 0.1 roentgen per 24 hours. Badges were generally issued for only one or a few days of the operation. It is estimated that about 15% of CROSSROADS naval personnel were issued film badges. To date, however, only about one-third of the Navy doses have been matched with name.

Overall, the radiation exposures for Operation CROSSROADS were relatively low. Approximately 99 percent of all recorded radiation exposures ranged from zero to 0.5 rem gamma. The highest recorded cumulative exposure for any individual at the operation was 4.01 rem gamma. This dose was received by an Army monitor. This exposure is within present national occupational radiation exposure standards which permit 5.0 rem per calendar year.

The following table summarizes the recorded CROSSROADS exposures available to date for naval personnel. Dosimetry data have only been found for 1,954 naval personnel as of January 1982.

PERSONNEL IN EACH GAMMA EXPOSURE CATEGORY

	Roentgens (R)					
	Zero Exposure	.001-.500	.501-1.00	1.001-2.000	2.001-3.000	Total Personnel
No. of personnel	1,125	812	13	3	1 *	1,954
Percent in each group	57.57	41.55	0.66	0.15	0.05	

*Highest Navy dose is 2.03 R

SUMMARY AND PAGE REFEERENCE
XRD-185, 186 and 187
OPERATION CROSSROADS

VOLUME 1 (XRD-185)

PAGE	SUMMARY OF DATA
21-22	Special precautionary measures established on August 29 by Commander Service Force Pacific for all vessels exposed to an accumulated time of ten or more days in Bikini Lagoon subsequent to July 25.
23	Clearance guidelines defined by the Force Medical Officer, Captain W. E. Walsh, (MC) USN.
43	Acid flush solutions found to undergo a chemical change forming new soluble compounds with carbonates phosphates and hydroxides resulting in a citric acid solution.
46	.01 R/day establsihed as an acceptable standard for maximum exterior radiation from salt water lines or machinery below which no decontamination is required.
54 & 59	Dr. Joseph G. Hamilton identified as a recognized radiologist associated with the University of California, J. G. Crocker Radiation Laboratory. He was one of six senior radiologists and radioactivity toxicologists on a special medical advisory board to counsel the Chief, Bureau of Medicine and Surgery on radiological matters.
56	Although plutonium was acknowledged on one of the more heavily contaminated non-target vessels, the material was reported to be so widely distributed in tons of rust, scale, paint and marine growth or in the some 125 tons used in sandblasting that it represented absolutely no hazard at all.

59	Reported that by January 1, 1947, a total of 80 vessels of the 159 non-targets had been granted final clearance. Conference on November 27 concluded that "There is absolutely no possibility of physical injury from radioactive materials in the amounts being dealt with on the non-targets under existing conditions".
60	November 27 conference concludes that sand and acid disposal present no security or health hazard. Minutes of the meeting summarized in a December 10, 1946 memo (see Volume 3, page 102).
60-61	University of California data indicates rapid decay of gamma radioactive material so that it appeared that all non-target ships would have final clearance by March 15, 1947.
61	Discussion of radiological condition on CROSSROADS non-target vessels.
62	After two months of experimental work, successful methods were developed to the extent necessary to eliminate all health and security hazards.
133	Technical instructions for monitors were developed to detect and avoid radiological hazards.
134	Maximum tolerable limit of occupancy set at 0.1 R of gamma per day (24 Hours).

SUMMARY AND PAGE REFEERENCE
XRD-185, 186 and 187
OPERATION CROSSROADS

VOLUME 2 (XRD-186)

PAGE

SUMMARY OF DATA

6 Readings obtained on the USS LAFFEY on September 5, 1946 indicated that the radioactivity on the hull was considerably below the danger level, thereby requiring no further measurements.

7 Test results showed that salt water systems were considerably more radioactive than the outside hull plating, but still not to the degree that would be unsafe for shipyard workers.

10 A September 10 memo to the Commander, San Francisco Naval Shipyard directed that all materials scraped from the side of the ship will be segregated and dumped at sea.

13 A Naval Shipyard Notice dated September 11 called for radiological clearance when the ships entered the yard.

21 A second barrel of flushing water from USS LAFFEY was declared safe for dumping into the Bay on September 18.

36 Directive from Rear Admiral T. A. Solberg, USN establshes procedures to dump all marine growth scrapings at sea. [SEE NOTE] Although desirable to decontaminate completely all salt water lines, when practicable, operative ships may delay such procedures.

41 Message to Navy Shipyard San Francisco on September 20 directs that prior to cleaning procedures scale should be dumped at sea.

VOLUME 2 (XRD-186) Cont.

86-87 An October 18 memo lists ten ships that took part in Bikini tests now at San Francisco Naval Shipyard.

94-95 Total areas on USS ROCKBRIDGE that had high reading spots are provided. This gives some idea of total surface areas that were sandblasted and show the requirement for 125 tons on sand.

104 An October 15 memo states that 3100 gallons are required to completely fill the fire and flushing systems aboard USS ROCKBRIDGE.

107 Fill capacity of the USS WALKE evaporator noted to be 950 gallons.

109 Fill capacity of each of the two evaporators on USS ROCKBRIDGE noted to be 1500 gallons each.

115 The University of California Radiation Laboratory missions are defined.

130 On September 26 the first barrel of flushing water from firemains on USS LAFFEY were found to be radioactive and were dumped at sea. The second barrel was found to be safe and the hose was led overboard to the Bay.

145 Breakdown and neutralization of hydrochloric acid flushing solutions is discussed.

SUMMARY AND PAGE REFEERENCE
XRD-185, 186 and 187
OPERATION CROSSROADS

VOLUME 3 (XRD-187)

PAGE	SUMMARY OF DATA
4-7	A directive issued on July 31, 1946 covered decontamination procedues for target vessels.
14	A message on September 4, directs San Francisco and others not to drydock Bikini vessels.
16-17	A September 24 letter authorizes drydocking but calls for scraping of marine growth and dumping such scrapings at sea. All sand used in sand blasting was to be collected and dumped at sea. Decontamination procedures were reviewed.
26	An initial organization for radiological monitoring and clearance of Bikini vessels was established on November 18, 1946 at Pearl Harbor, Puget Sound San Francisco, Mare Island and Terminal Island. This organization replaced the Joint Task Force One organization and was to advise Shipyard Commanders of what portions of vessels require decontamination and to insure compliance with BUSHIPS directives.
29	A November 22 message established that all ships will get an initial clearance after monitoring, followed by an operational clearance, good only until such time that a final clearance standards are applicable.
30-51	A November 22, 1946 directive provided procedures for radiological clearance, decontamination and established standards for CROSSROADS non-target vessels. It pointed out that fittings and equipage in contact with sea water will be contaminated as well as concentrated in marine growth, rust, scale and salt scale deposits.

VOLUME 3 (XRD-187) Cont.

32-33 Operational Clearance and Final Clearance are defined and the readings necessary to reach these clearances are provided.

35-37 General radiological safety precautions for CROSS-ROADS vessels are covered in detail.

38-49 Radiological decontamination procedures are covered for evaporators, saltwater systems, condensers and main condensers, underwater body, ship boats, and hull, hull fittings and deck equipment.

53 A December 4 message for the first time allows disposal or acid in the Bay at a slow rate so as to dilute the solution about one fourth. Special disposal of sand used in wet sandblasting underwater bodies which does not contain marine growth no longer required. Marine growth and scale must still be collected and disposed of at sea.

54 A December 17 letter provides changes to the November 22 procedures and formally established changes in above message. All rust and marine growth from initial scrapings must still be disposed of at sea.

60 Dr. Hamilton advises that marine growth be kept wet until it can be dumped at sea.

61-73 Discussions at October 1 conference at San Francisco Naval Shipyard provide insight into concern and effort ongoing to insure safe procedures. On page 67 Dr. Scott indicates that it would be safe to clean ships 100 times as active as USS LAFFEY. Dr. Rodenbaugh cautioned that no chances should be taken in regards to issues that might present a health hazard.

68 The terms "active ship", "deactivated ship" and "target ship".are defined.

VOLUME 3 (XRD-187) Cont.

74	BUSHIPS message of October 10 establishes readings necessary for final clearance.
78	ADM Solberg advises that salt water lines and evaporators on target ships will not be a problem becuase these systems were not in use on these targets during the period of possible contamination.
84	The Medical Advisory Board establishes the tolerance figures for final radiological clearance on October 18, 1946.
102-115	The memorandum of December 10, 1946 provides the minutes of the Conference on Radiological Safety held at BUSHIPS, Washington D.C. This memo provides the quotes used in the January 15, 1982 San Francisco Chronicle article.
108	ADM Solberg states that "it is not likely that any problem will arise as a result of radioactivity on target ship bottoms".
109	Dr. Hamilton states that the local disposal of acid and sand containing some fission products absolutely does not entail a health or security hazard.
122	BUSHIPS letter of January 14, 1947 established the procedures for radiological examination of CROSSROADS target ships.